OPERANT PROCEDURES IN THE AUDITORY ASSESSMENT OF "DIFFICULT-TO-TEST" INDIVIDUALS

An abstract of a Thesis by
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June 1978
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The problem. Standard audiometric assessment procedures are not effective in testing some mentally retarded individuals for sensory capabilities. The present study investigated the use of operant conditioning procedures to determine hearing threshold levels with profoundly retarded individuals.

Procedure. Three profoundly retarded individuals were trained to respond on an FR 2 or 3 schedule of reinforcement to puretone presentations of several frequencies (500, 1000, 2000, and 4000 Hz). Then, hearing thresholds were determined for each subject using two types of threshold tests, the descending-series method and a trials-wise tracking procedure, the staircase method. The order of threshold test administration was counterbalanced across subjects.

Findings. Reliable hearing threshold levels were obtained within subjects and within the type of threshold test employed. All subjects were observed to "track" their own threshold levels with the staircase procedure, and the obtained threshold levels were similar to or lower than those produced with the descending-series method.

Conclusions. The systematic employment of operant conditioning procedures enabled the production of hearing thresholds with "difficult-to-test", profoundly retarded individuals. A trials-wise tracking procedure, or staircase method, proved to be very functional in the determination of sensory capabilities with such individuals.

Recommendations. In order to assess the auditory capabilities of "difficult-to-test" individuals, the clinical investigator should (1) employ operant conditioning training procedures to ensure increased control of the subject's behavior in the clinical situation, and (2) use testing procedures which allow for the attainment of both reliable and valid sensory profiles.

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A Thesis

Presented to

The School of Graduate Studies

Drake University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

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by

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June 1978

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Chapter I

INTRODUCTION

The determination of puretone, auditory thresholds with "normal" individuals is a standard audiometric procedure. The individual to be tested is brought to the testing-room and given specific instructions by the audiologist. Such instructions involve a description of the signal-detection response (e.g., saying the word "yes", raising an arm, etc.) to be employed by the individual tested. Once these instructions are well understood, puretone threshold testing is begun with the individual emitting the instructed response whenever an auditory signal is detected. Failure to respond to an auditory signal indicates a failure to "hear" the signal.

This traditional procedure assumes (1) the individual-to-be-tested is capable of understanding complex instructions, and (2) the individual can emit the required signal-detection response. Audiometric assessment of mentally retarded individuals, particularly the severely and profoundly retarded, cannot take such assumptions for granted. These individuals are typically non-verbal and can, at best, follow only simple, one-part instructions (e.g., "Billy, come here"; "Debbie, stand-up"). Therefore, special audiometric assessment procedures have had to be developed to determine the auditory functioning of severely and profoundly retarded individuals.

Work in this regard was prefaced by the development of operant methods for obtaining psychophysical thresholds with pigeons (Blough, 1958; Heise, 1953), rats (Clack & Harris, 1963), and monkeys (Clack & Herman, 1963; Stebbins, Green, & Miller, 1966; Symmes, 1962). Two general paradigms for the assessment of sensory capabilities emerged from these investigations. First, use of a single-response manipulandum (e.g., circular key, lever) proved workable. Here, responses to the desired stimulus (e.g., brief-tone presentation) were positively reinforced, while responses in the absence of that stimulus (i.e., errors or false reports) were discouraged through the use of a mild punishing consequence (e.g., brief time-out). Other investigators (c.f. Blough, 1966, pp. 345-379) found the two-response manipulanda paradigm to be more useful. The second manipulandum was used for responding in the absence of stimulus presentations, or responding to sub-threshold stimulus levels. Such responding was typically reinforced by presentation of the designated stimulus. This paradigm had the added advantage of greater control over the subject's behavior between stimulus presentations.

Applications of operant procedures to the determination of auditory deficits with "difficult-to-test" individuals have primarily involved the single-response manipulandum paradigm. These applications may be best understood by a review of both the training and testing approaches employed.

Training Approaches

A crucial component in determining reliable, puretone thresholds has been the development of auditory stimulus control over responding. Emitting the required response to tone presentations, when no tone is present, are typically termed as errors, or false positive responses. In differential discrimination training, such errors are given the opportunity to occur, allowing some programmed consequence to decelerate their frequency. Investigators have reported that these errors are sometimes difficult to eliminate (Fulton & Spradlin, 1974a, pp. 13-27; Meyerson & Michael, 1960). Indeed, experimental studies of visual discriminations with retarded children have demonstrated that "errors create more errors" (Sidman & Stoddard, 1966).

Terrace (1963a) developed a method to train color discriminations with pigeons in an errorless fashion. A characteristic feature of this method was the progressive introduction of the negative stimulus (S-) along both brightness and duration dimensions. Then subjects were given only a very limited opportunity to err during the initial stages of discrimination training. This opportunity to err was gradually increased as discrimination training progressed. In addition, transfer of stimulus control from color to form was accomplished in an errorless fashion (Terrace, 1963b). Superimposing the irrelevant dimension (i.e., form) on the previously relevant dimension (i.e., color), and then gradually fading out the color, became the crucial aspect of this latter procedure.

Employment of these "errorless" discrimination procedures in the audiometric assessment of "difficult-to-test" individuals has been reported (Bricker & Bricker, 1969a; Lloyd, Spradlin, & Reid, 1968; Meyerson & Michael, 1960). A common technique has been to train subjects to respond initially to a lighted response key or lever. Once subjects have demonstrated adequate discrimination performance to the light, a tone is paired with the light. The light is then gradually faded out until the tone alone is controlling the detection response. Use of this procedure, however, does not preclude the occurrence of errors during the initial establishment of the light as a discriminative stimulus. The progressive introduction of S- duration (i.e., the gradual increase in the duration of S- as training progresses) would be necessary for minimizing errors during this aspect of training. While such a technique has been employed (Bricker & Bricker, 1969a), its contribution to overall stimulus control training and eventual threshold testing remains in question (Bricker & Bricker, 1969b).

Testing Approaches

A common method of threshold measurement has been the descending-series threshold test, as described by Carhart & Jerger (1959). The audiologist presents a series of puretones in descending order until a false report occurs, or the subject fails to respond to a puretone presentation. Then, the puretone intensity is increased 10-20 dB, and a new series is begun. A minimum of three such series is necessary.

Employment of this method has been based on clinical observation and logic. It has been argued that the suprathreshold presentations inherent in the descending-series method provide (1) greater consistency between training and testing sessions, (2) more opportunity to reinforce appropriate responses, (3) the opportunity to program generalization to many puretone intensities, and (4) less opportunity for the occurrence of errors, or false reports (Lloyd, 1975, pp. 1-36). Some experimental evidence has suggested (Fulton & Spradlin, 1974b, pp. 37-52) that the testing method which affords the greatest stimulus control during testing sessions will yield the most reliable and valid threshold data.

Other testing methods employed in operant research include the "staircase" method (Cornsweet, 1962), the "titration schedule" (Weiss & Laties, 1958), the "adjusting" method (Sidman, 1962), and threshold "tracking" (Blough, 1958). Despite specific procedural and situational differences (e.g., free-operant versus trial-wise procedures), these methods share a common denominator, i.e., stimulus presentations are contingent upon the subject's behavior, with the resultant threshold reflecting moment-to-moment changes in the subject's behavioral-sensory capabilities. For example, if the subject correctly detects a puretone presentation, it would serve to lower the intensity of the next presentation by five decibels. Failures to respond, or false reports, would serve to raise the intensity of the next presentation by five decibels.

While these latter types of testing methods have been widely used in obtaining psychophysical thresholds with experimental animals (i.e., rats, monkeys, and pigeons), no applications with "difficult-to-test" individuals have been reported. An emphasis on training procedures, as well as a concern for the maintenance of stimulus control during testing sessions, has precluded any such applications. The present study investigated a trials-wise, auditory threshold tracking method (i.e., the "staircase" procedure) with profoundly retarded individuals. Employing errorless discrimination, stimulus control training procedures, threshold levels obtained with this testing method were compared with those yielded by the descending-series threshold method.

Chapter II

METHOD

Subjects

Three profoundly retarded residents of Woodward State Hospital-School, one male (P-2) and two females (P-1 and P-3), served. They ranged in age from 17 to 26 years, and averaged 17 years of institutionalization each. All had been previously untestable with standard audiometric procedures. All three subjects received some form of medication (e.g., phenothiazine, anti-convulsant) while participating in the current study, but dosages remained constant. To ensure the absence of middle-ear pathologies which might have affected the subjects' hearing levels, pre- and posttest tympanograms were obtained by a certified audiologist. No significant changes in middle-ear function were noted.

Apparatus

A 52 x 39 x 47 cm human operant conditioning console was employed. The front panel of the console contained two 4 x 6 cm translucent response keys, spaced 26 cm apart. Two other pairs of smaller, white keys, 3.5 x 3.5 cm, were located between the larger response keys. In the present investigation, only the large, left response key, and a smaller, adjacent white key were used. All other keys on the panel were non-functional throughout the present study. The functional keys were illuminated with 6.3 v white lights, located directly behind each key. A 35 msec light flash on the smaller key was perfectly paired with the delivery of an edible reinforcer. A 6.3 v white session light was located at the center of the consoles front panel. This light was continuously operated during all sessions.

A David Scientific Instruments (DSI) M & M dispenser (model no. MM D-2) was located in a small box (20.5 x 30 x 30 cm) adjacent to the console. It dispensed M & Ms through a 1.5 x 15.0 cm tube into a small plastic tray attached to the front of the box. The console and reinforcer box were placed on a table in a small training room.

For all tone presentations, a portable MAICO audiometer (model MA-2B), and accompanying supraaural earphones, were employed. The intensity output of the audiometer was calibrated to ANSI (1969) levels. Pre- and poststudy calibration checks of the audiometer showed no significant change in output intensity, suggesting that it remained in calibration throughout the investigation. All measures of hearing reported in this study are in decibels (dB) in relation to audiometric zero (hearing level).

The subject room was a 2.4 m x 2.2 m x 2.0 m cement-block enclosure without windows, but with no special acoustic seal on the door. In order to assess the possible effects of background noise on hearing measures, thresholds of "normal" individuals were obtained in the room at times when Ss would normally be tested. Thresholds as low as 5 dB were obtained across all test frequencies. It was demonstrated that under usual testing conditions, ambient noise would not adversely affect measures of hearing level.

Training Procedures

Pretraining. Each subject was adapted to the experimental room, magazine trained, and given earphone training. Initially, subjects were brought to the experimental room for brief periods of time (i.e., 5-10 minutes) and seated in front of the training console. Edible reinforcers were delivered and were contingent upon (1) an absence of "tray-tending" (i.e., keeping hands out of an empty reinforcer tray), (2) the omission of self-stimulatory behavior, and (3) wearing the designated earphones. The number of reinforcers delivered and session times were gradually increased until each subject had received at least 30 edible reinforcers within one 15-20 minute session. In addition, each subject must have worn the earphones throughout this session. Once these criteria were met, key-press training began.

Key-press training. Initially, subjects were physically prompted to press the illuminated, large key. These prompts were gradually faded until each subject was responding independently. Prior to advancement to the next training phase, each subject was required to (1) independently produce at least 30 edible reinforcers on a fixed-ratio (FR) 1 schedule of reinforcement, and (2) distribute responses such that interresponse times (IRTs) ranged from 0-20 seconds.

Auditory stimulus-control training. Then, responding was reinforced only during the discriminative stimulus (S^D), a key-light of 120 seconds duration, and not during S-delta ($S\Delta$), a dark key present for 4 seconds. A key-press response during S^D periods produced (1) a brief light flash (35 msec), (2) an edible reinforcer, (3) S^D offset, and (4) $S\Delta$ onset. Responses during $S\Delta$ (i.e., errors or false reports) precluded onset of the next S^D period for 4 seconds. Over sessions, the duration of the S^D period was gradually reduced to a fixed-time of 10 seconds. Concomitantly, the duration of $S\Delta$ periods was gradually increased to a variable-time of at least 10 seconds. Upon reaching this point, subjects were advanced through the rest of the program only when they responded correctly to 80% of the S^D periods, as well as emitting 80% correct responses throughout one entire session.

When stimulus control by the key-light had been reached, a 750 Hz (1500 Hz for P-3), 70 dB hearing level (HL) puretone was paired with the key-light during S^D periods. This puretone was presented through the right earphone only. Moreover, the schedule of reinforcement was changed from an FR 1 to an FR 2 or 3 schedule. When the stimulus control criterion had been reached for the light-tone S^D, the key-light fading sequence began. This sequence totaled 11 linear units, with a correction procedure determining the particular sequence for each subject. Responding correctly to an S^D presentation advanced the sequence by one unit. An incorrect response, i.e., any response occurring during SΔ periods, reversed the sequence by one unit. Furthermore, the failure to respond correctly to three consecutive S^D presentations reversed the sequence by one unit. Meeting the 80% stimulus control criterion with the puretone alone as the S^D was required prior to advancement to the next training phase.

Tone-generalization training. Programming stimulus generalization to frequencies of 500, 1000, 2000, and 4000 Hz was required before threshold testing could begin. These frequencies were presented in a consecutive fashion (e.g., 5 trials at 500 Hz, 5 trials at 1000 Hz, etc.) at 70 dB during all sessions. As in previous phases, each subject received edible reinforcers for correct S^D detections. Meeting the 80% stimulus control criterion with all puretone frequencies presented within a session was required prior to threshold testing.

Testing Procedures

Each testing session was preceded by a 10-trial, stimulus control assessment period. All four testing frequencies were presented, and meeting the standard stimulus control criterion was required before testing proceeded. It was only possible to gather threshold data from one puretone frequency per test session. Therefore, each complete threshold test required a minimum of four sessions. Probe trials were employed when subjects demonstrated hearing levels of 20 dB or lower at any particular frequency. These trials involved presenting an inaudible puretone during a testing sequence to determine whether any extraneous cues were affecting the subject's behavior. Their use was limited to one trial per test session. As in previous phases, edible reinforcers were delivered for correct tone detections. All testing was performed for the right ear only with all subjects.

Descending-series threshold test. Beginning with the puretone intensity at which training had been conducted, a series of puretone intensities, gradually decreasing by 5 decibel units, were presented. When a detection failure or false report was observed, the intensity level was increased 20-30 dB and a new descent initiated. At least three descents were required, and each test session was terminated when 30-40 edible reinforcers had been delivered.

Staircase threshold test. Each session began at the puretone intensity where stimulus-control training had been conducted. Each subsequent tone presentation was dependent upon the subject's response to the previous presentation. If a puretone was correctly detected, the intensity of the next tone was decreased five decibels. False reports, or failures to detect a particular tone, increased the intensity of the next tone presentation by five decibels. Each test session terminated when 30-40 edible reinforcers had been delivered.

Experimental Design

The focus of the current investigation was upon obtaining reliable, within-subject threshold data both within and across the types of threshold tests employed. The first two subjects, P-1 and P-2, received three consecutive descending-series threshold tests, followed by a test using the staircase method. The third subject, P-3, received three consecutive staircase threshold tests, followed by a descending-series threshold test. This testing arrangement allowed for an evaluation of the two threshold testing methods employed, by counterbalancing their presentations for any possible order effects.

Chapter III

RESULTS

The total training time averaged 5.75 hours, with each subject requiring 3.71 hours (P-1), 3.57 hours (P-2), and 9.97 hours (P-3), respectively. The additional training time with P-3 was spent attempting to achieve criterion-level, stimulus control with an FR 3 schedule of reinforce-emtn for each puretone presentation. This response require-ment was eventually reduced to FR 2, and within 1.2 training hours, criterion-level stimulus control by the puretone was achieved.

For P-1 and P-2, threshold testing involved three descending-series threshold tests and one staircase threshold test. Hearing level profiles approximating a U-shaped curve were obtained with these subjects during the descending-series threshold tests, as shown in Figure 1. Each data point represents the median of the low points for nine threshold sweeps (three per test) with each subject. The low point was the lowest hearing level to be correctly detected. For P-1, lower and less variable hearing determin-ations were demonstrated at 2000 and 4000 Hz. Except for 500 Hz, these levels all lie within or very near the normal range of hearing. Thus, no apparent hearing loss was evi-denced. For P-2, lower and less variable hearing levels were obtained at 1000 and 2000 Hz. The specific hearing levels,

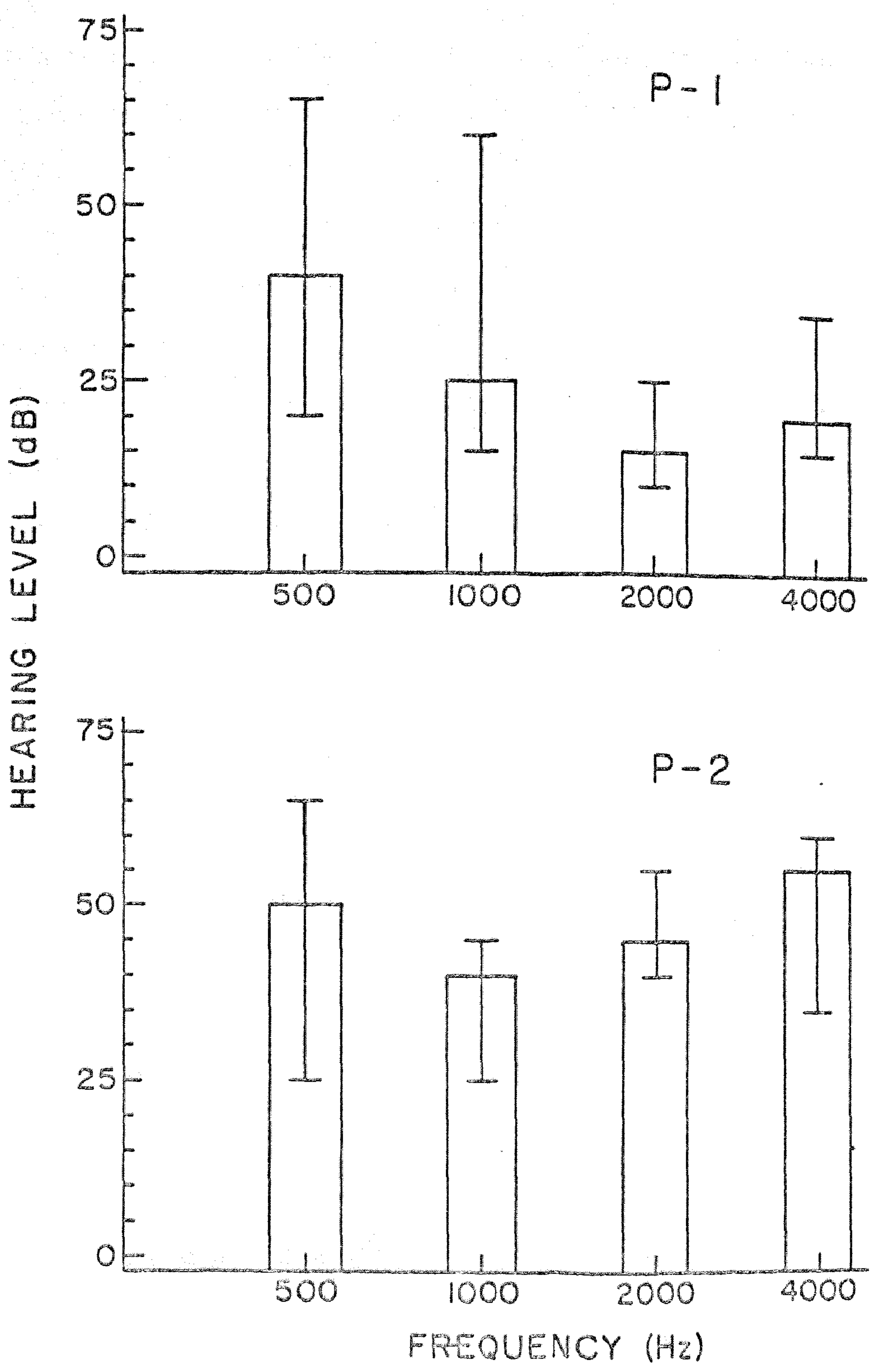

Figure 1. Median hearing threshold levels for P-1 and P-2 during descending-series threshold testing. Each data point represents the median value of nine threshold sweeps, with the surrounding brackets indicating the range of these sweeps.

with medians ranging from 40-55 dB HL for the four testing frequencies, suggest a possible hearing loss with this subject.

Both P-1 and P-2 demonstrated consistent performances during individual descending-series sessions. The initial descending-series session at 500 and 1000 Hz with P-1 produced elevated hearing levels, as shown in Figure 2. Subsequent sessions at 500 Hz produced lower levels, reaching the lowest point of successful detection of 30 dB during session DS-2 and 20 dB during DS-3. Subsequent sessions at 1000 Hz also produced lower hearing levels, reaching low points of 10 dB in DS-2, and 15 dB in DS-3. For 2000 Hz, a low point of 15 dB was obtained during the initial session (DS-1). Sessions DS-2 and DS-3 corroborated this result reaching low points of 10 and 20 dB, respectively. With 4000 Hz, a low point of 15 dB was attained in DS-1. Sessions DS-2 and DS-3 produced similar results, reaching low points of 15 dB in each session. However, the variability shown in DS-3 exceeded that obtained in DS-1 and DS-2.

The low hearing levels demonstrated by P-1 necessitated the employment of probe trials (i.e., presentation of 0 dB) during the descending-series testing sessions. No detection responses were observed for any of the seven probe trials employed, thus adding to the validity of the obtained hearing measures.

For P-2, the initial descending-series session for

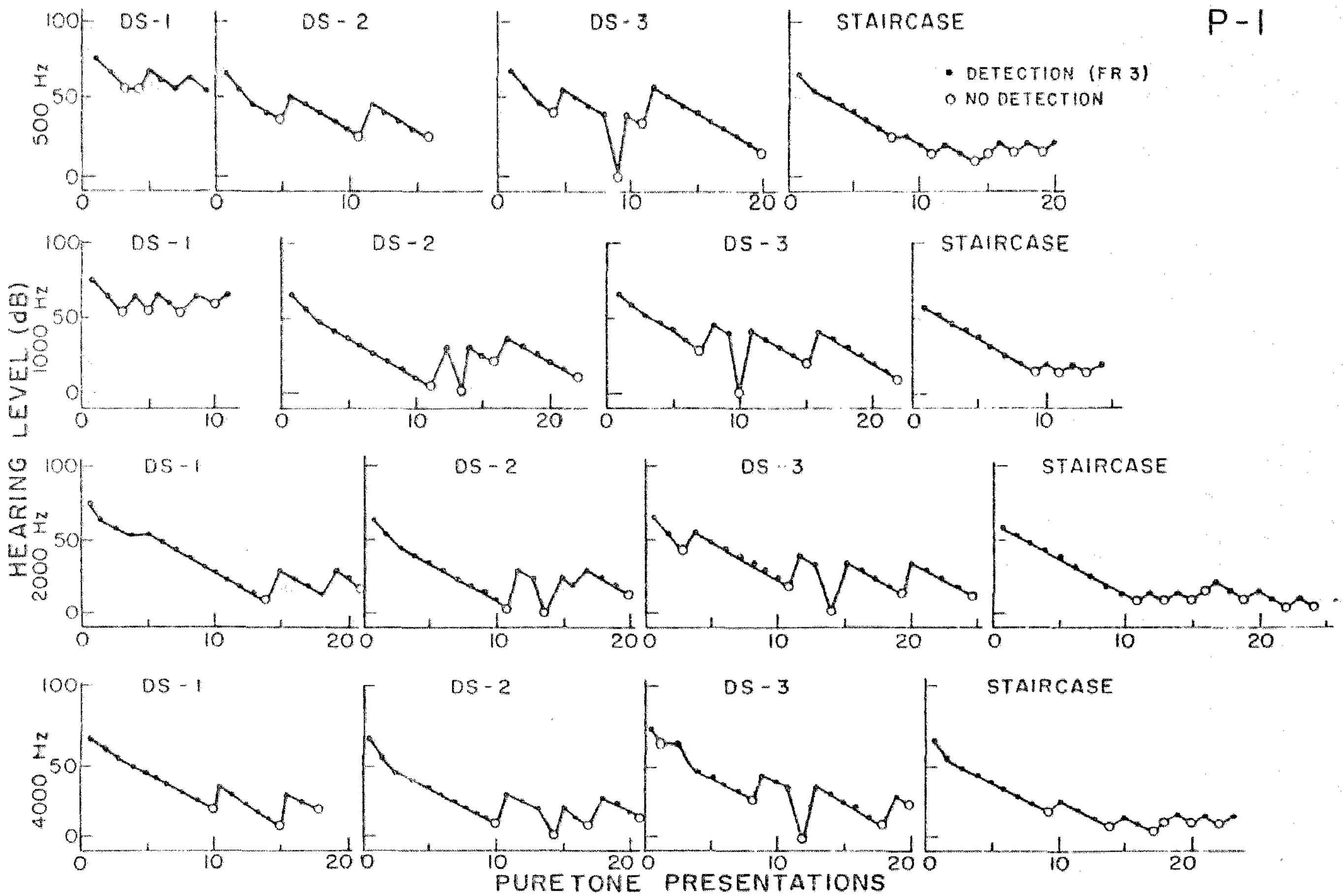

Figure 2. Individual test session performances for P-1 during descending-series (DS) and staircase threshold tests.

500 Hz (DS-1) produced hearing levels which reached a low point of 25 dB, as shown in Figure 3. Sessions DS-2 and DS-3 produced higher levels, reaching a low point of 45 dB in each session. At 1000 Hz, a low point of 40 dB was obtained in the initial descending-series session (DS-1). Session DS-2 produced a lower hearing level, reaching a low point of 25 dB on two of the three threshold sweeps. In DS-3, hearing levels approximating those demonstrated in DS-1 were produced, with a low point of 40 dB obtained. For 2000 Hz, a low point of 40 dB was attained in the initial descending-series sessions (DS-1). Subsequent sessions (DS-2 and DS-3) confirmed this result, reaching low points of 45 dB in each session. The initial descending-series session at 4000 Hz (DS-1) produced a low point of 50 dB, with increased variability in performance observed. A slightly lower hearing level was shown in DS-2, reaching a low point of 35 dB. The last session (DS-3) produced a low point of 45 dB, thus approximating those levels demonstrated in DS-1.

Hearing level determinations with the staircase threshold test were found to match those obtained with the descending-series test for both P-1 and P-2. For P-1, the staircase session at 500 Hz (Figure 2) produced a low point of 15 dB, with the hearing level stabilizing at 20 dB. A similar level was reached during the final sweep of session DS-3. At 1000 Hz, the staircase session stabilized at the 20 dB level, approximating those low points produced during

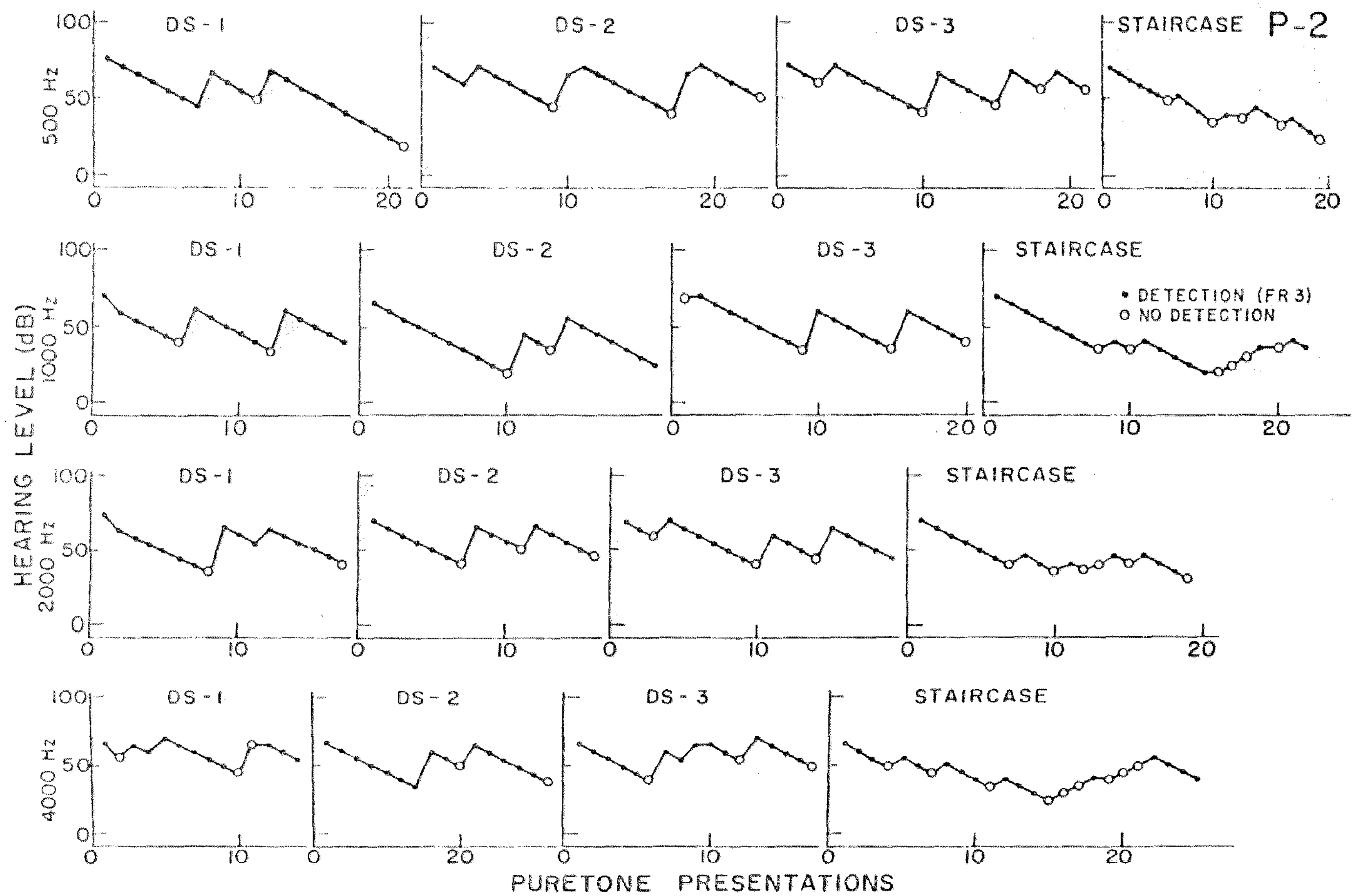

Figure 3. Individual test session performances for P-2 during descending-series (DS) and staircase threshold tests.

sessions DS-2 and DS-3. For both 2000 and 4000 Hz, low points of 10 dB were reached during staircase sessions, with performance stabilizing in the 10-20 dB range. These levels matched those produced by previous descending-series sessions at both testing frequencies.

For P-2, the staircase session at 500 Hz (Figure 3) produced a low point of 30 dB, which was slightly lower than those levels obtained in sessions DS-2 and DS-3. A threshold sweep ending at 25 dB was observed during session DS-1, however. At 1000 Hz, a low point of 20 dB was demonstrated during the staircase session, with the hearing level stabilizing at 35 dB. This approximated those levels obtained in session DS-2, and is slightly lower than those levels demonstrated in sessions DS-1 and DS-3. For 2000 Hz, the staircase session produced a hearing level which stabilized between 35 and 45 dB, thus approximating those levels demonstrated in previous descending-series sessions. The staircase session at 4000 Hz produced a low point of 30 dB, but did not stabilize at any particular point. The lowest point reached during previous descending-series sessions had been 35 dB.

Puretone threshold testing for P-3 consisted of three staircase threshold tests, and one descending-series threshold test, at each testing frequency. In the staircase-1 session at 500 Hz, shown in Figure 4, performance stabilized at the 30 dB level. Subsequent staircase sessions failed to corroborate the results of this initial session. In the

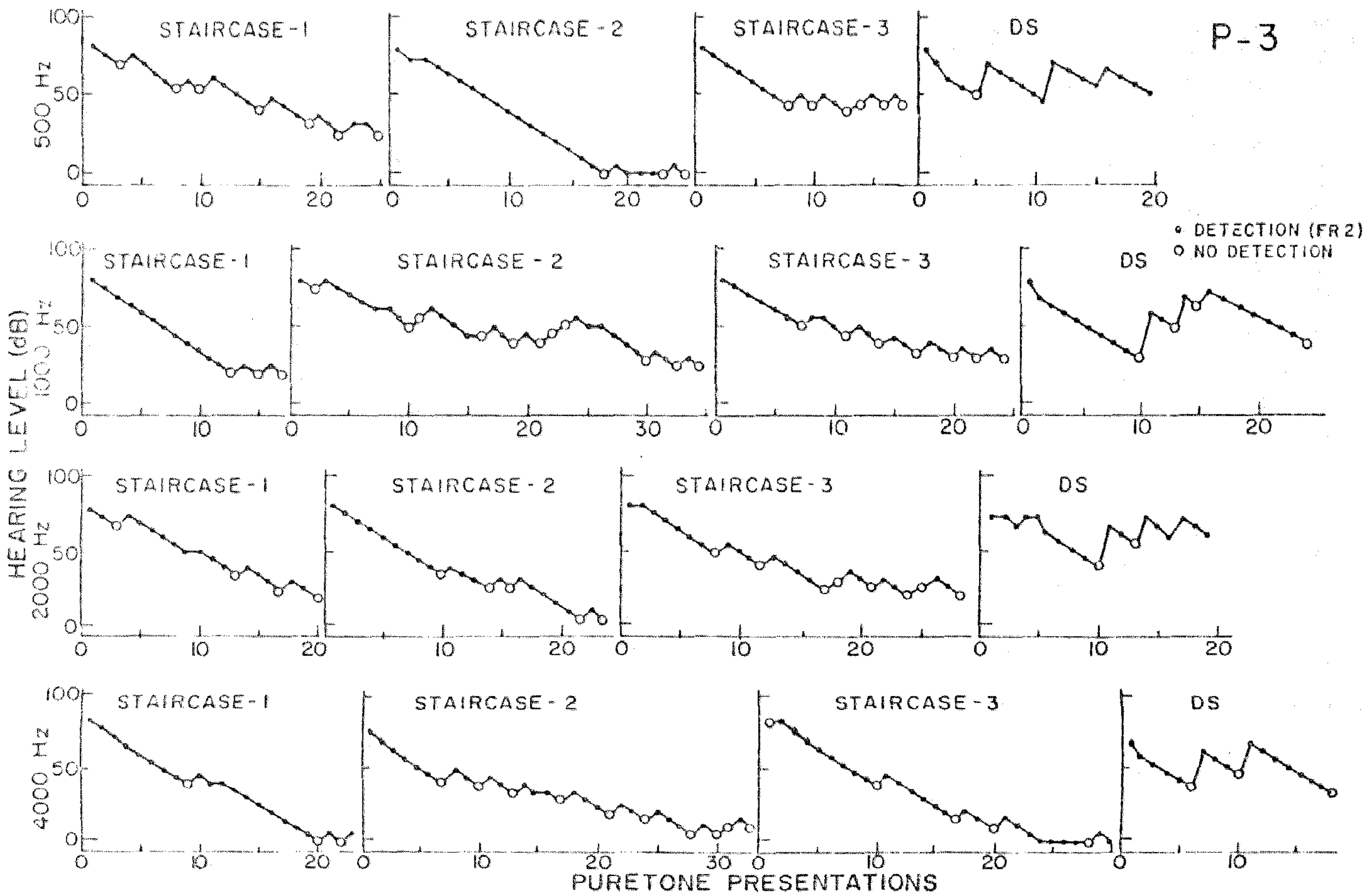

Figure 4. Individual test session performances for P-3 during staircase and descending-series (DS) threshold tests.

staircase-2 session, a low point of 0 dB was reached, with P-3 successfully detecting this intensity three out of six times. Staircase-3 produced a low point of 45 dB, which was higher than those levels shown in both previous sessions. Thus, three different hearing levels emerged from the staircase sessions at 500 Hz.

At the other testing frequencies, more consistent performance across individual staircase sessions was observed. At 1000 Hz, a low point of 25 dB was reached in the initial staircase session. Both subsequent sessions, staircase-2 and staircase-3, confirmed these initial results, with low points of 30 and 35 dB being observed, respectively. For 2000 Hz, a low point of 25 dB was obtained in staircase-1, although it is unclear whether performance had stabilized at that point. Staircase-2 produced lower hearing levels, with performance stabilizing at the 10 dB level. Staircase-3 produced a hearing level matching that of staircase-1, with a low point of 25 dB obtained. The lowest hearing levels for P-3 were demonstrated at 4000 Hz. A low point of 5 dB was reached in the first staircase session (staircase-1), with performance stabilizing at that point. Subsequent sessions replicated these results, with levels of 10 dB and 0 dB being attained, respectively.

The descending-series threshold test produced consistently high hearing levels across all four testing frequencies for P-3. The descending-series session for 500 Hz produced levels which reached a low point of 45 dB, thus matching the results of the previous staircase-3 session. For 1000 Hz, a similar result was obtained, with the hearing level produced in the descending-series session matching that of the staircase-3 session. However, this level exceeded those produced in the first two staircase sessions at 1000 Hz. For both 2000 and 4000 Hz, the descending-series sessions produced hearing levels which exceeded those of all previous staircase sessions. Low points of 45 and 40 dB for 2000 and 4000 Hz, respectively, were reached during these descending-series sessions.

P-3 was observed to detect a 0 dB puretone five out of six times during staircase-3 at 4000 Hz. Previously, P-3 had "bottomed-out" during staircase-2 at 500 Hz, detecting a 0 dB tone three out of six times. Those data prompted a subsequent staircase session at 4000 Hz, with the addition of the presentation of a no-tone trial (i.e., completely turning off the audiometer) when 0 dB was successfully detected. The session produced a hearing level reaching 0 dB, with 0 being successfully detected two out of three times, as depicted in Figure 5. In addition, the no-tone trial was successfully detected, suggesting that P-3 was responding to cues other than just the puretone itself during this session. No attempt was made to determine these cues.

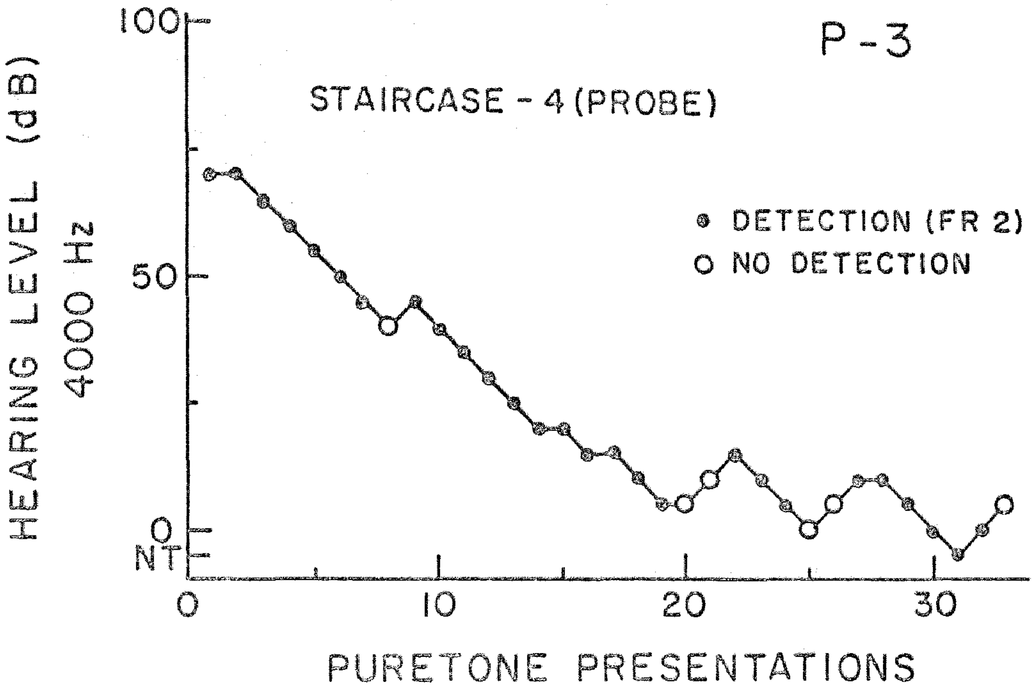

Figure 5. An additional staircase session for P-3 at 4000 Hz. This session featured a no-tone probe trial (NT) contingent upon a detection response to a 0 dB presentation.

Chapter IV

DISCUSSION

The present study represented an investigation of operant procedures for the auditory assessment of three profoundly retarded individuals. The systematic employment of stimulus control training procedures enabled the production of hearing thresholds using two threshold testing methods, the descending-series method and a trials-wise tracking procedure, the staircase method. Reliable hearing levels (±10 dB), both within subjects and within the type of threshold method, were observed. Two subjects (P-1 and P-2) were administered three descending-series threshold tests, followed by a staircase test, while one subject (P-3) received three staircase threshold tests, followed by a descending-series test. Hearing levels produced by the staircase procedure were equal to or slightly lower than those levels produced by the descending-series method for both P-1 and P-2. For P-3, hearing levels produced by the staircase procedure were substantially lower than those produced by the descending-series method.

Procedural differences between the two testing methods may account for the between testing method discrepancies. One such procedural difference is the intensity changes which follow detection failures and false positive responses. With the descending-series method, detection failures and false positive responses produced subsequent intensity increases of 10-20 dB (i.e., reinitiation of a threshold sweep). These response patterns produced intensity increases of 5 dB in the staircase procedure.

It may be that such response patterns in the descending-series method, by being consequated with greater intensity increases, become more probable. Previous psychophysical research (Blough, 1958; Stebbins et al., 1966) has suggested that changes in stimulus intensity could serve as a reinforcing event for observing responses, especially when such changes were followed by a response producing unconditioned reinforcers. In the present study, the louder the tone became (i.e., up to 70 dB), the more conditions approximated those in which responses were reinforced in the past and the less they were like conditions in which responses were not reinforced. Responses, then, which produced greater intensity increases would have a higher probability of being maintained. Thus, threshold sweeps would be shortened, resulting in the attainment of higher threshold levels.

Another alternative may be that the rules inherent in the use of the descending-series method serve to limit the opportunity for the attainment of lower threshold levels. That is, by requiring the reinitiation of a threshold sweep with the greater intensity increases, a greater total testing time is spent at suprathreshold levels, thus limiting the number of those stimulus presentations at or below the subject's actual threshold level.

Such between testing method discrepancies in the present investigation may also be due to order effects. An analysis of the data shows that more consistently lower hearing levels were obtained with the staircase procedure by P-3, than by P-1 or P-2. Both P-1 and P-2 received the staircase procedure after the descending-series test, while the reverse occurred for P-3. It may be that the order in which such tests are administered could greatly determine the attained hearing levels.

Whatever the reason, the implications of such differences are twofold. First, clinical investigators would be hard-pressed to employ one testing method (e.g., the staircase procedure) as a source of validity for another testing method without an in-depth analysis of the respective contingencies of reinforcement established by each test. Such a concern would be especially acute when dealing with the "difficult-to-test" individual. Second, such an analysis leads the investigator into the realm of signal-detection theory (c.f. Green & Swets, 1966). This theory's emphasis on motivational factors and response bias from moment-to-moment provides the operant practitioner with a worthwhile tool in the analysis of sensory deficits.

A noteworthy feature of the present testing analysis was the use of non-audible or sub-threshold probe trials within the context of both the descending-series and staircase testing methods. Their value lies primarily in the confirmation of normal hearing level determinations (i.e., when threshold levels of 0-20 dB are produced), rather than in just a general use to determine the degree of control exerted by extraneous cues. Thus, the clinical investigator could employ such probe trials to make certain that those individuals diagnosed as having normal hearing, do not have mild or moderate hearing losses instead.

While the emphasis of the current investigation was upon a comparison of two threshold testing methods, several aspects of the stimulus control training procedures warrant discussion. First, a multiple-response requirement within a 10-second puretone presentation was employed, rather than a single-response requirement within a 3-5 second stimulus presentation. It remains unclear how each of these general procedures affect subsequent threshold testing, but it would not be unreasonable to expect such effects to be differential. For example, due to gross and fine motor handicaps with some profoundly retarded individuals, long stimulus presentations (e.g., 12-15 seconds) with small multiple-response requirements (e.g., FR2) may be necessary. Such situations would more than likely produce different sensory threshold levels than paradigms using short stimulus presentations (e.g., 3-5 seconds), with a single detection response requirement. Moreover, the ratio of an individual trial's duration to the intertrial interval would appear to be an important component in eventual threshold testing, as such a ratio would determine the opportunity for false reports.

The application of errorless discrimination training procedures represented a key aspect in the present study. The progressive introduction of SΔ duration, as well as the gradual transfer of stimulus control from light to tone, minimized errors (i.e., false reports) during the training phase for all subjects. But, the use of such procedures failed to circumvent the occurrence of errors during subsequent threshold testing. It appeared that such errors were induced by the testing procedures, as a reduction in puretone intensity is tantamount to fading out a discriminative stimulus without systematically programming the transfer of such control to other stimuli. Extraneous cues (e.g., temporal variables), then, begin to exert more control over the subjects' detection responses. Thus, the value of errorless training procedures for subsequent audiometric assessment remains unclear.

Another critical component of training was the stimulus generalization training phase. In the current investigation, generalization to all puretone testing frequencies was programmed. However, no systematic attempt to program generalization to other intensities was conducted. In the case of P-1, the absence of such a phase may have hindered initial threshold testing, as numerous errors were observed in the first threshold testing session, when the intensity of the tone was decreased. Previous exposure to tones of differing intensities, with detection responses to such tones being positively reinforced, may increase the validity of initial threshold testing attempts.

In summary, significant features of the present investigation include the employment of (1) errorless discrimination, stimulus control training procedures, (2) a trial-wise, threshold tracking procedure (i.e., the staircase method), and (3) a comparison of this threshold testing method with the more traditional, descending-series testing procedure. All subjects were observed to "track" their own hearing levels with the staircase procedure, producing slightly lower hearing levels than those produced with the descending-series testing method. The present data indicate that the staircase procedure represents a viable threshold testing method for "difficult-to-test" individuals.

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